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(54) **MICROELECTROMECHANICAL DEVICE WITH SIGNAL ROUTING THROUGH A PROTECTIVE CAP**

(71) Applicant: **STMICROELECTRONICS S.R.L.**, Agrate Brianza (IT)

(72) Inventors: **Giorgio Allegato**, Monza (IT); **Barbara Simoni**, Bareggio (IT); **Carlo Valzasina**, Gessate (IT); **Lorenzo Corso**, Ruginello (IT)

(73) Assignee: **STMICROELECTRONICS S.R.L.**, Agrate Brianza (IT)

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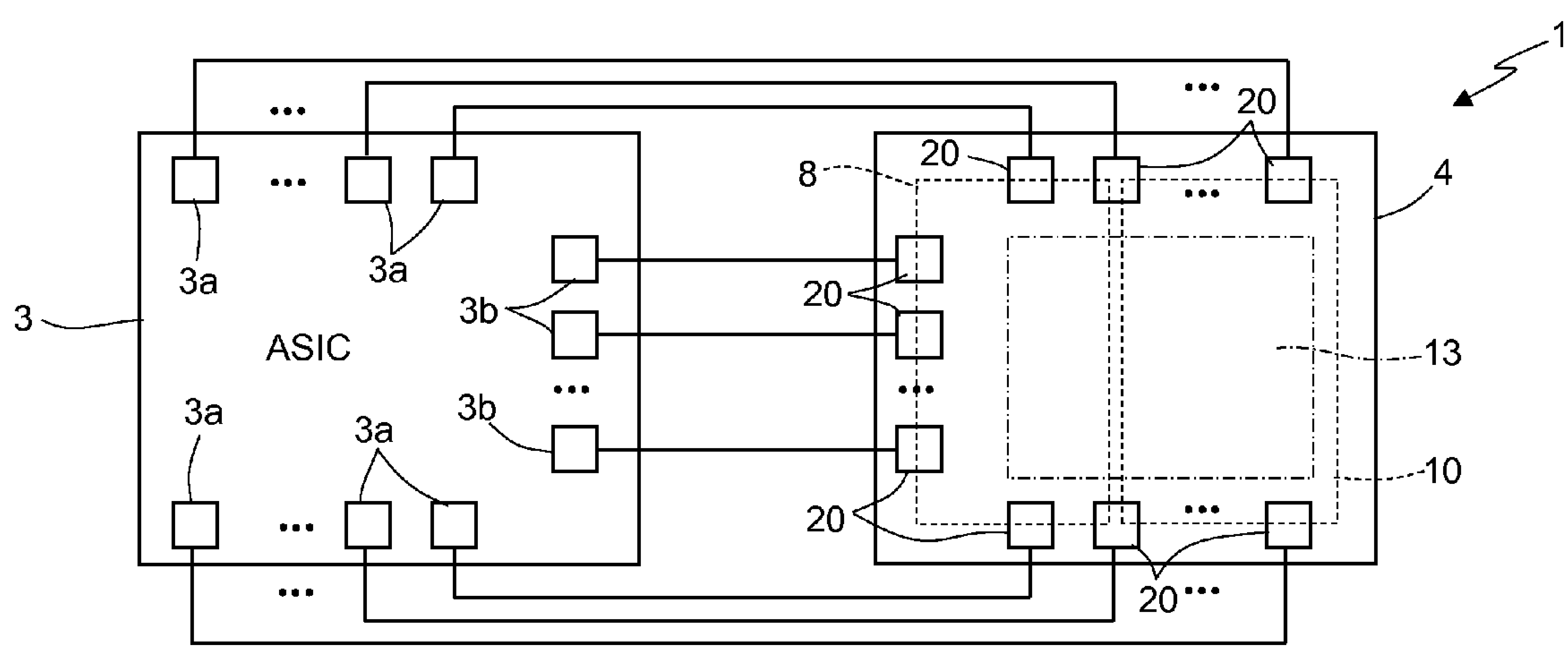
Primary Examiner — Paul West
Assistant Examiner — Mark A Shabman
(74) *Attorney, Agent, or Firm* — Seed Intellectual Property Law Group LLP

(57) **ABSTRACT**

A microelectromechanical device includes: a body accommodating a microelectromechanical structure; and a cap bonded to the body and electrically coupled to the microelectromechanical structure through conductive bonding regions. The cap including a selection module, which has first selection terminals coupled to the microelectromechanical structure, second selection terminals, and at least one control terminal, and which can be controlled through the control terminal to couple the second selection terminals to respective first selection terminals according, selectively, to one of a plurality of coupling configurations corresponding to respective operating conditions.

20 Claims, 10 Drawing Sheets



(52) **U.S. Cl.**
CPC ***B81C 1/0023*** (2013.01); *B81B 2201/0235* (2013.01); *B81B 2201/0242* (2013.01); *B81B 2207/012* (2013.01); *B81B 2207/015* (2013.01); *B81B 2207/07* (2013.01); *B81B 2207/092* (2013.01); *B81B 2207/093* (2013.01); *B81B 2207/096* (2013.01); *B81B 2207/097* (2013.01); *B81C 2203/0118* (2013.01); *B81C 2203/0792* (2013.01); *H01L 2924/0002* (2013.01)

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Fig.1

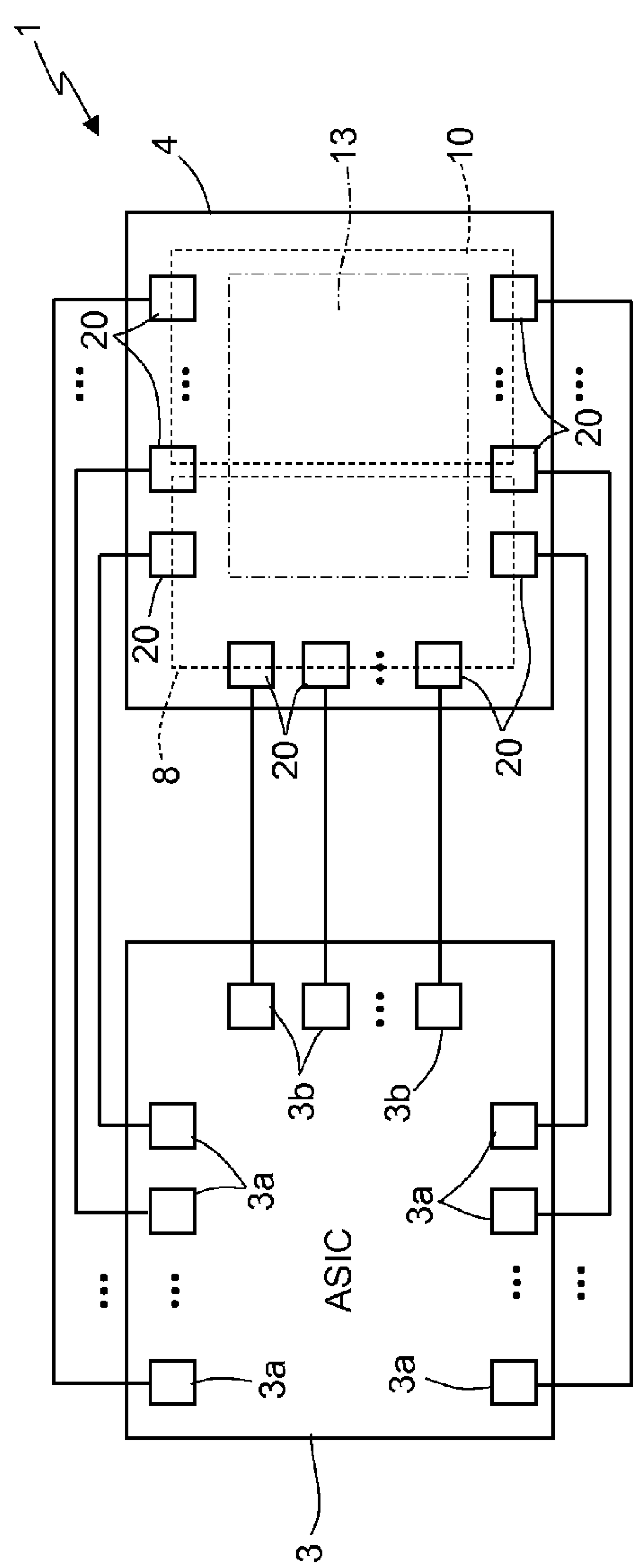
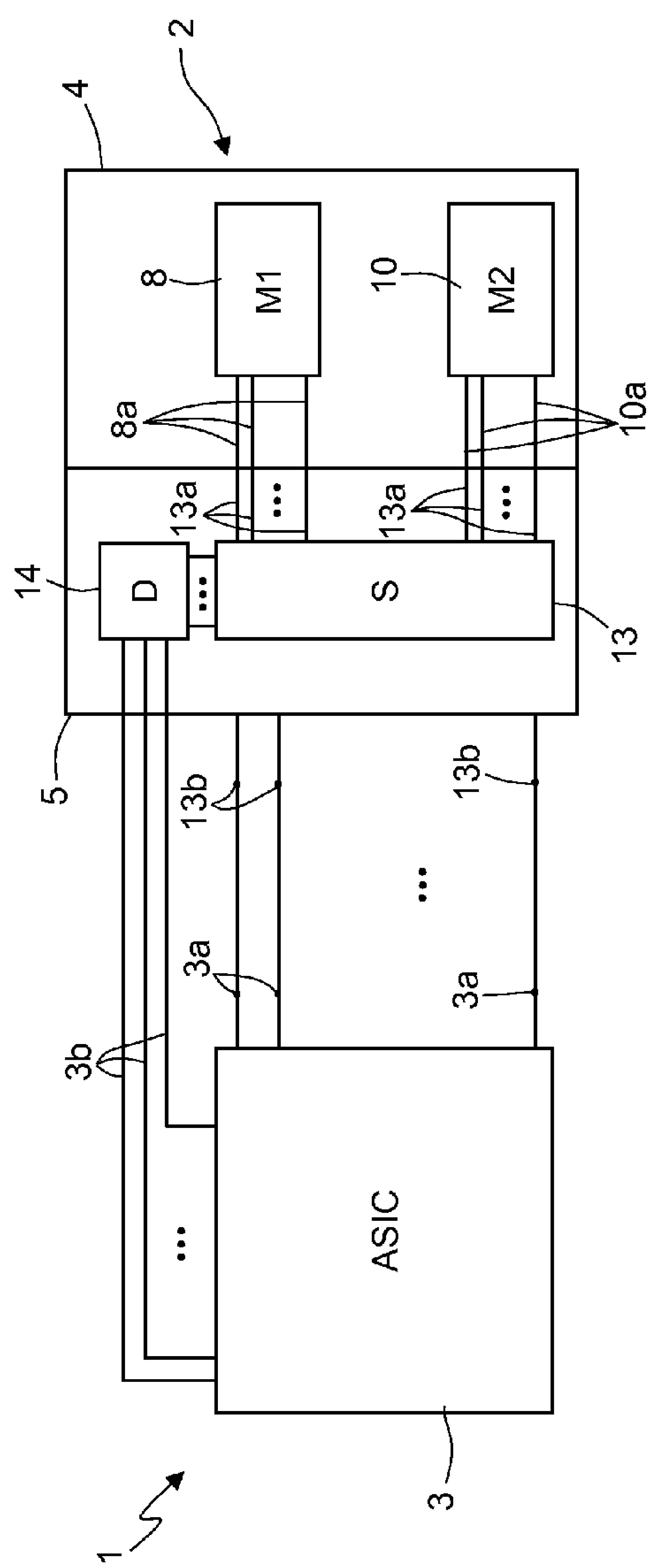

1
4
13
10
20
8
3b
3a
ASIC
3

Fig.2


2
4
8
M1
10
M2
8a
10a
13a
14
D
S
13
5
13b
3a
3b
ASIC
3
1

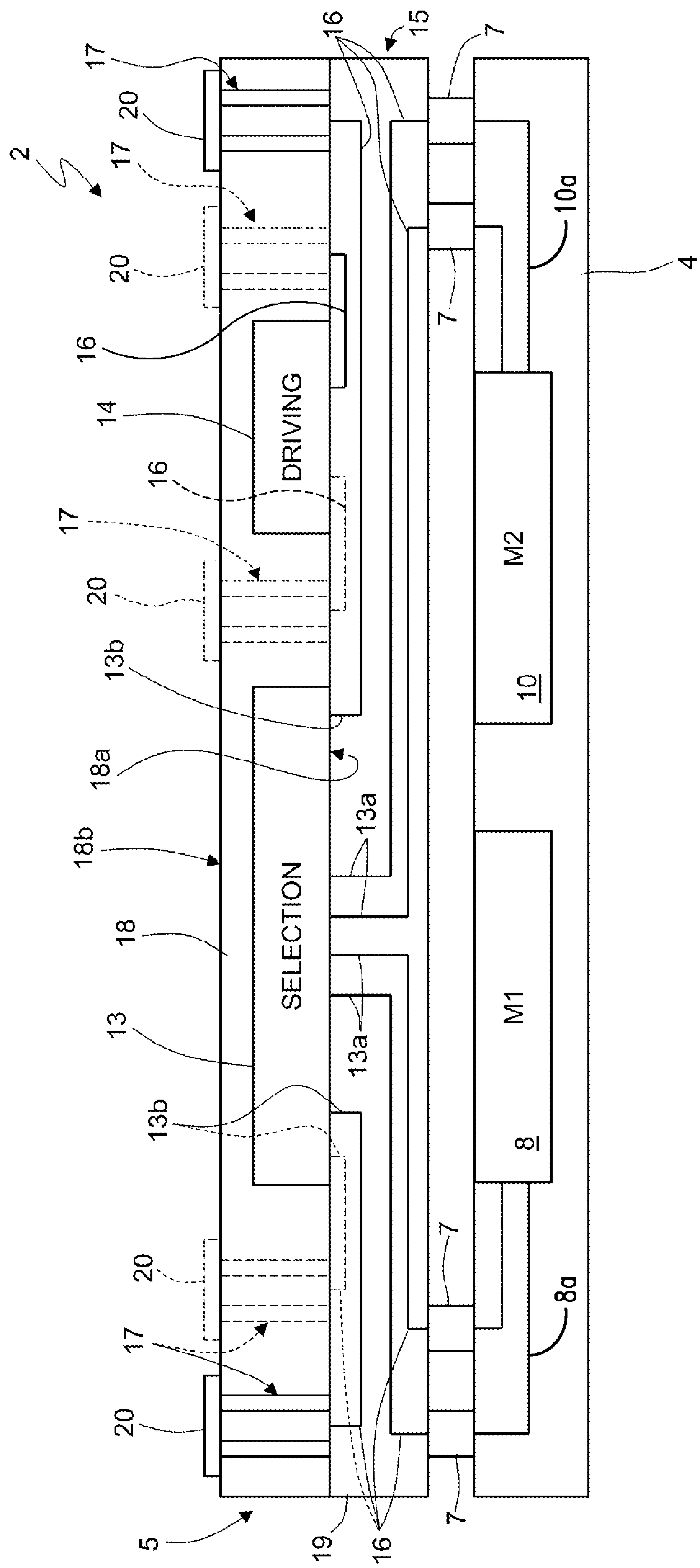

DRIVING
SELECTION
M1
M2
2
4
5
7
8
8a
10
10a
13
13a
13b
14
15
16
17
18
18a
18b
19
20

Fig.3

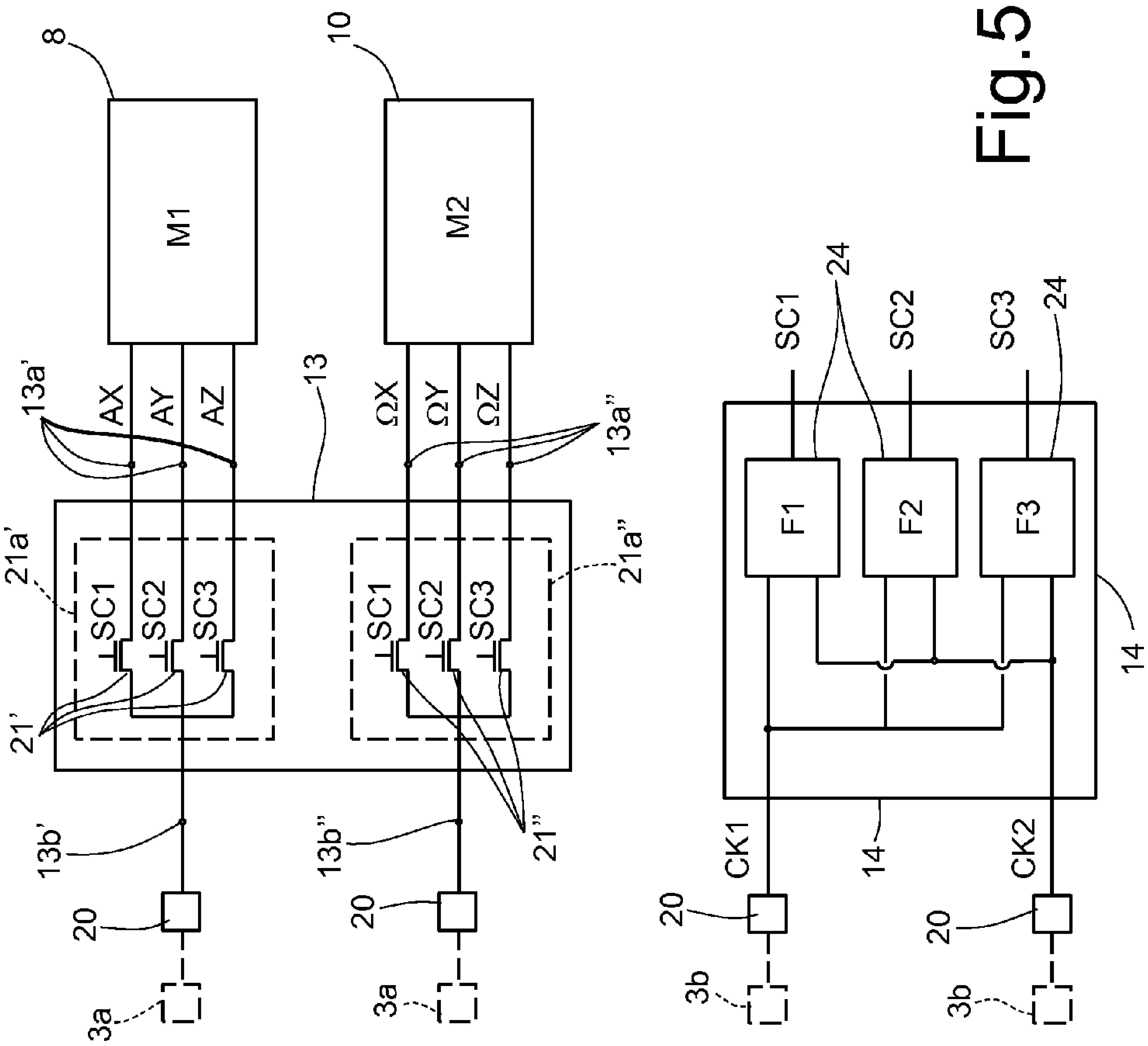

8
10
M1
M2
13a'
AX
AY
AZ
13
ΩX
ΩY
ΩZ
13a"
21a'
SC1
SC2
SC3
21a"
21'
21"
13b'
13b"
20
3a
SC1
SC2
SC3
24
F1
F2
F3
14
CK1
CK2
3b

Fig.5

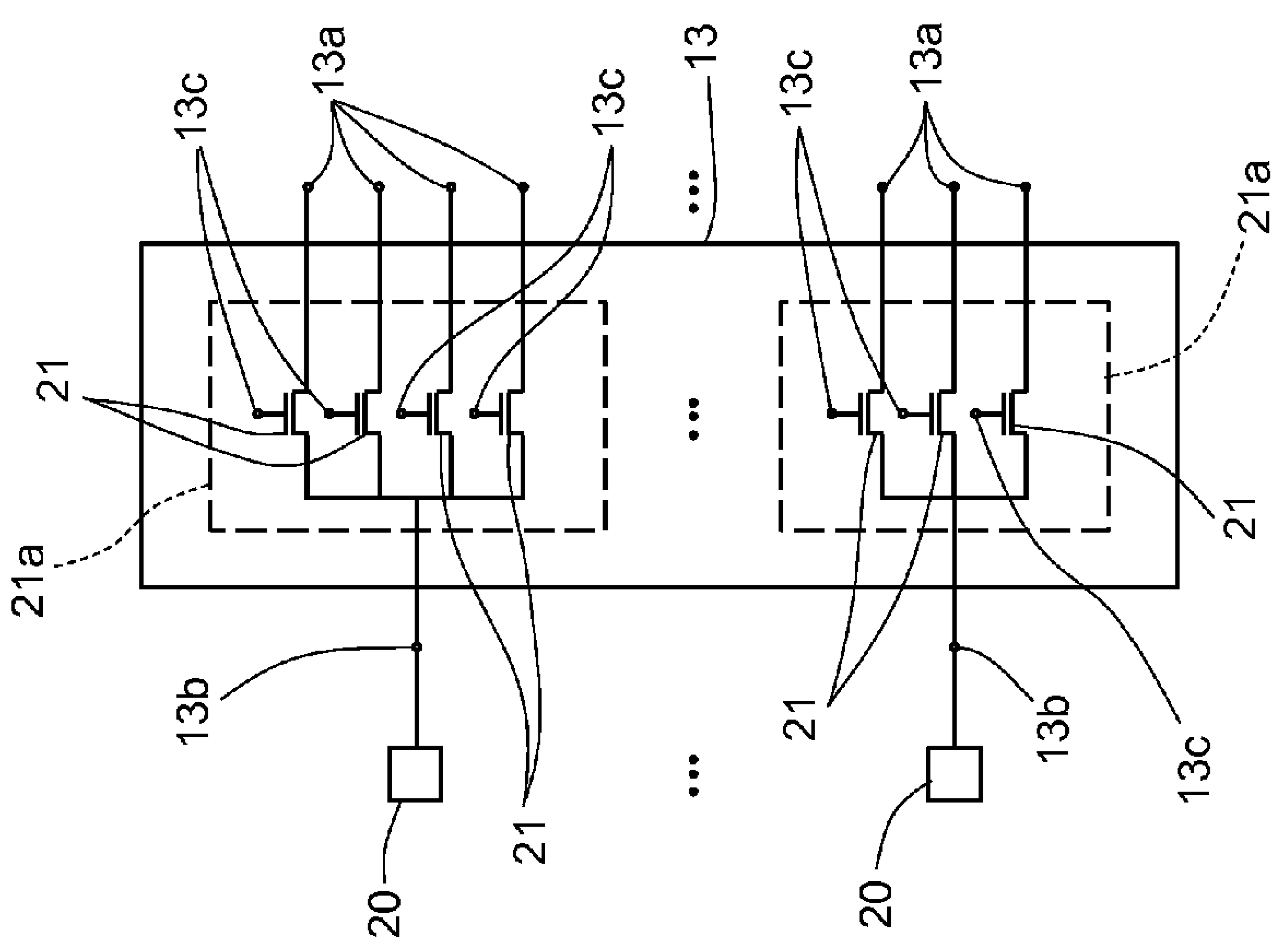

13c
13a
13c
13
13c
13a
21a
21
21a
21
13b
21
13b
13c
20
21
20

Fig.4

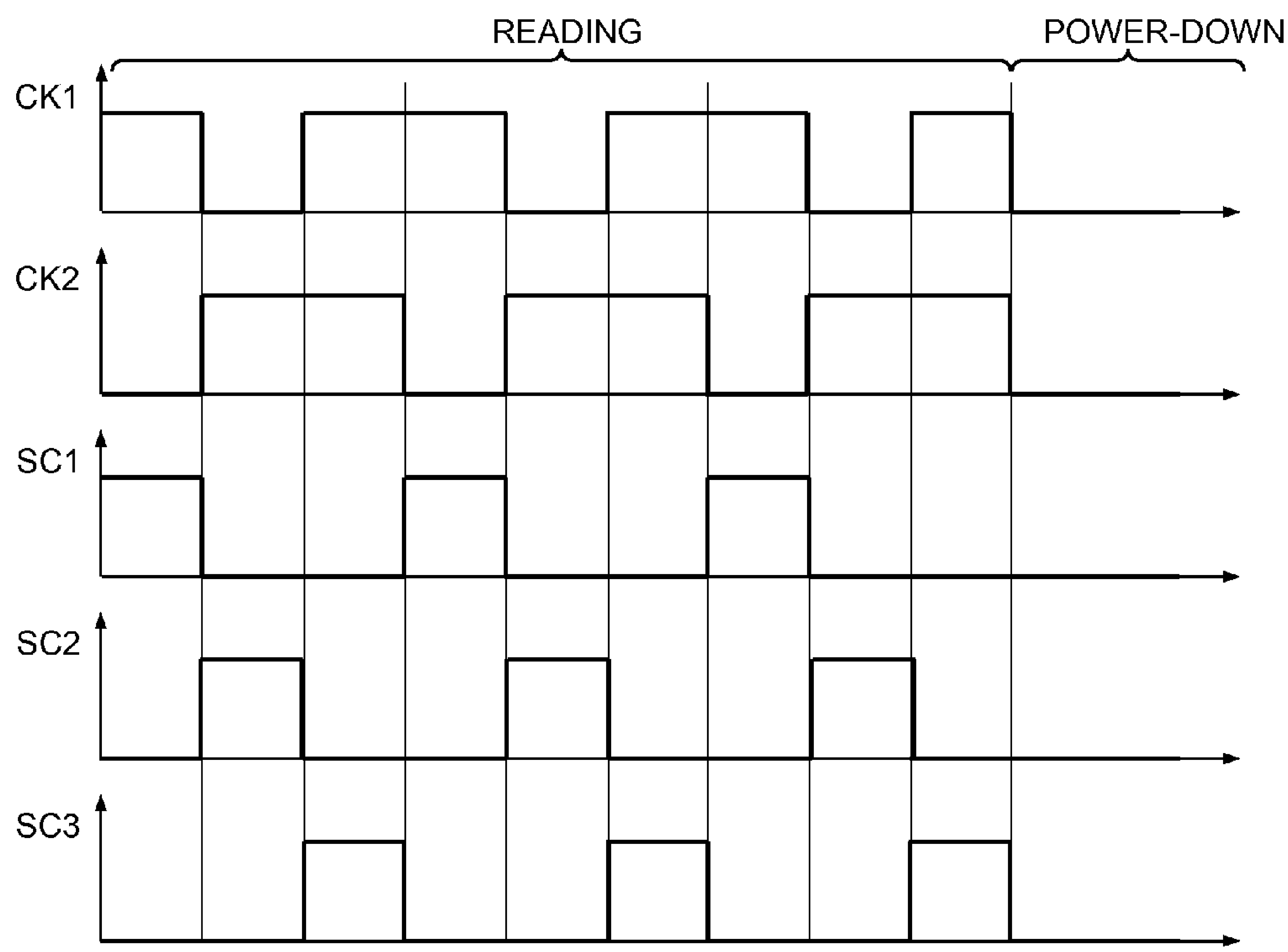


Fig.6

F1		
CK1	CK2	SC1
0	0	0
0	1	0
1	0	1
1	1	0

F2		
CK1	CK2	SC2
0	0	0
0	1	1
1	0	0
1	1	0

F3		
CK1	CK2	SC3
0	0	0
0	1	0
1	0	0
1	1	1

Fig.7

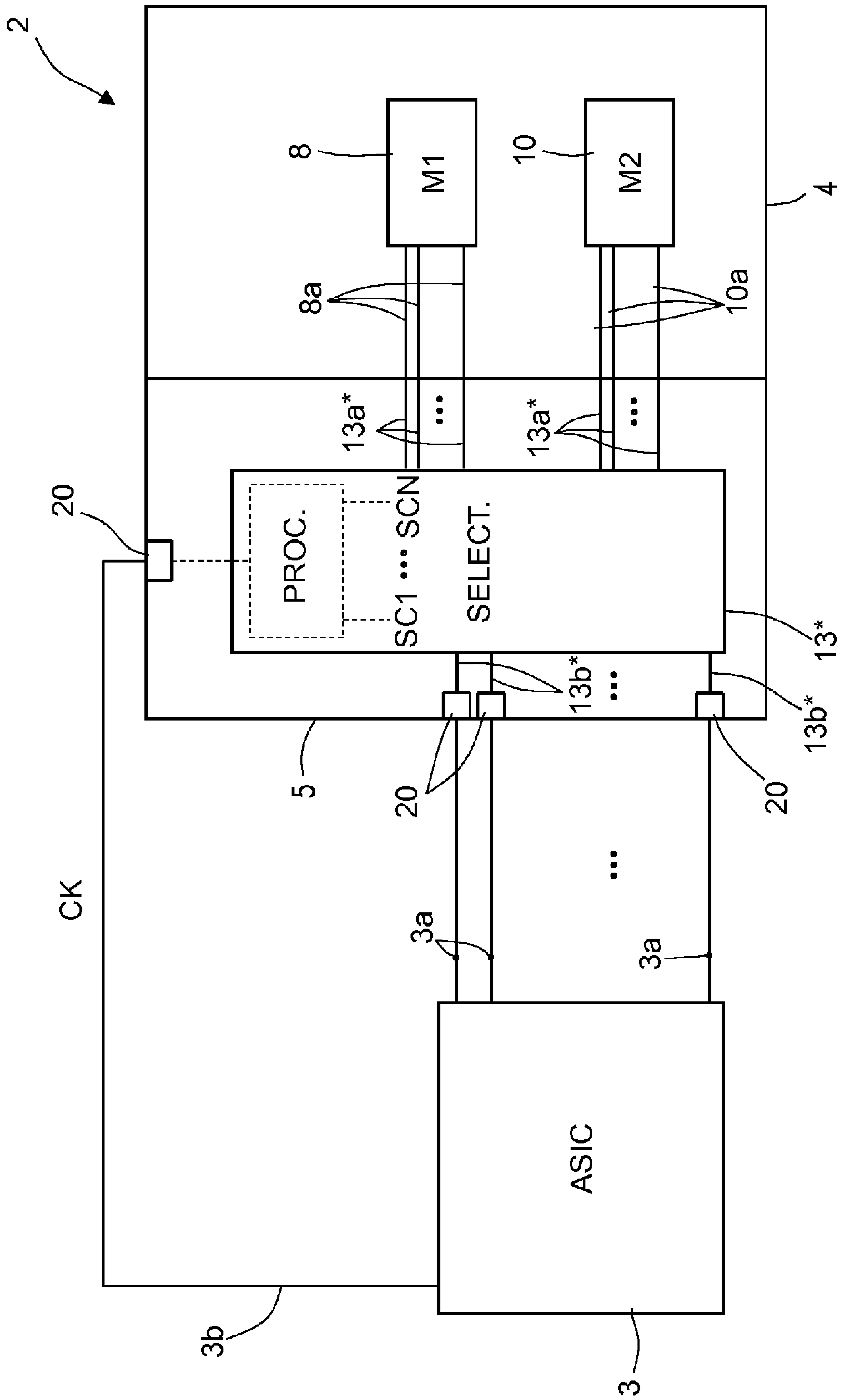

2
8
M1
10
M2
4
8a
10a
13a*
13a*
20
PROC.
SC1 ••• SCN
SELECT.
13*
13b*
13b*
5
20
20
CK
3a
3a
ASIC
3b
3

Fig.8

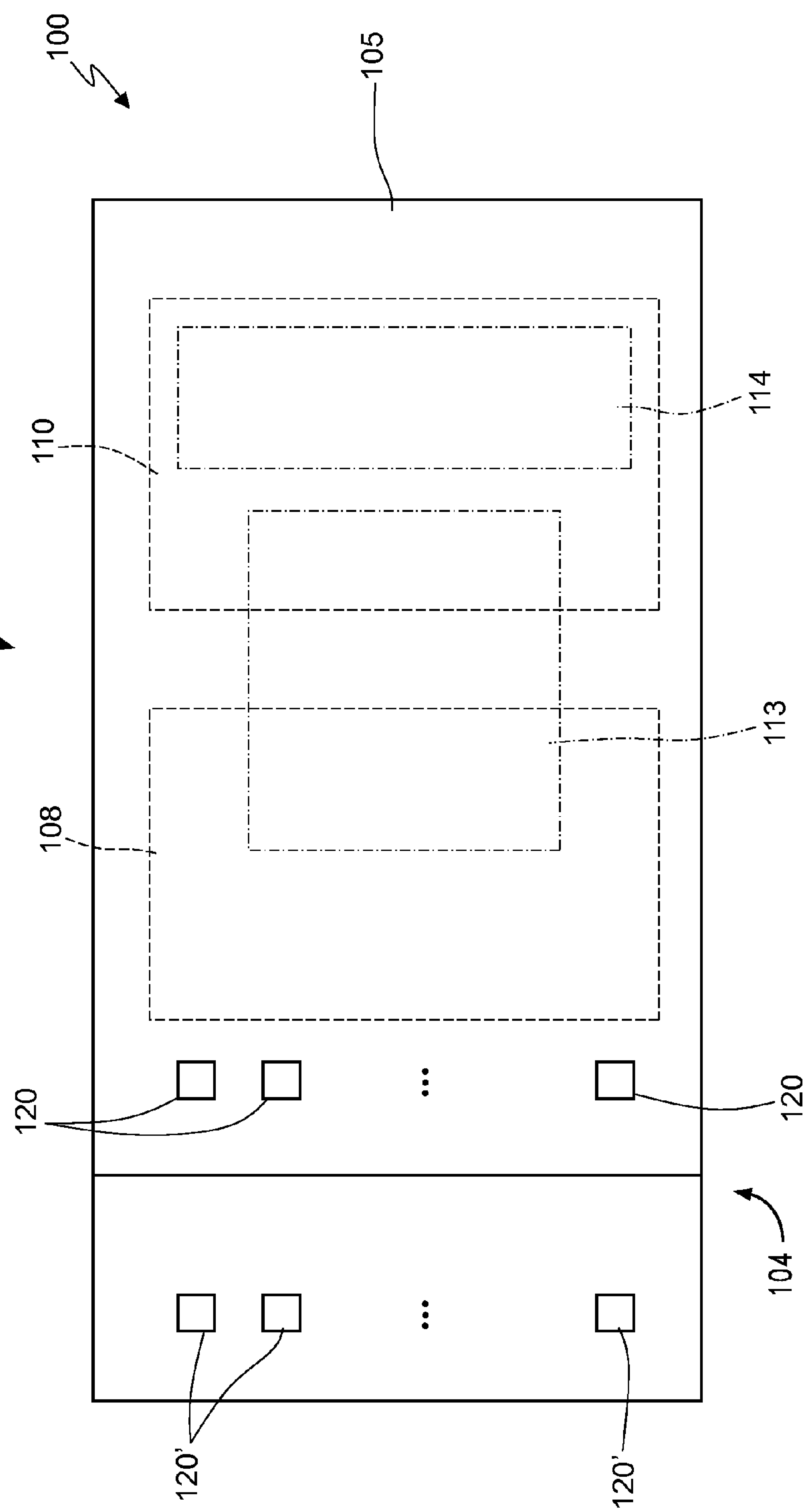


Fig.9

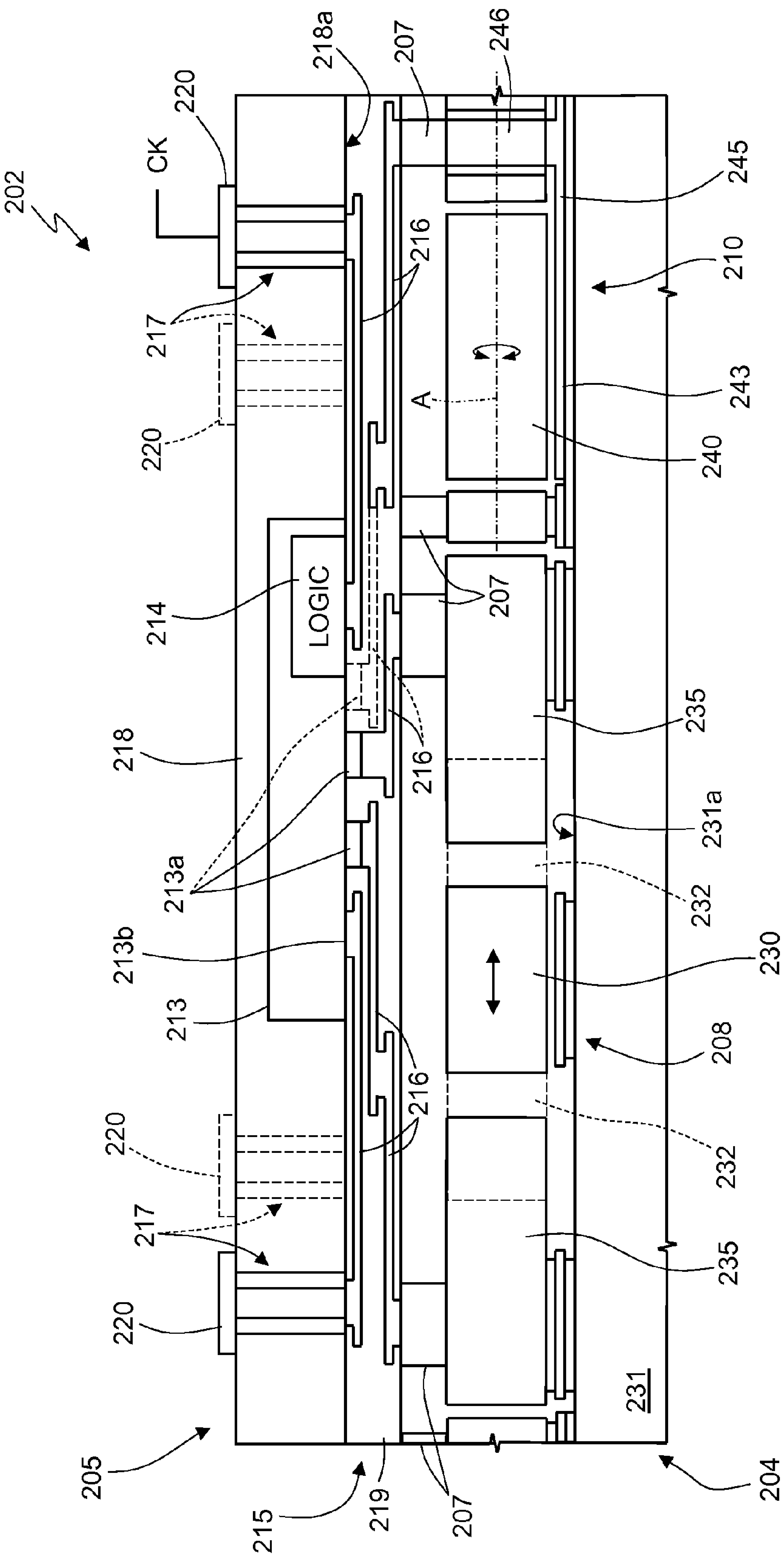

202
220
CK
218a
207
246
245
216
210
217
243
A
240
220
214
LOGIC
207
235
218
216
231a
213a
232
213b
230
213
208
220
216
217
232
235
220
231
205
215
219
207
204

Fig.10

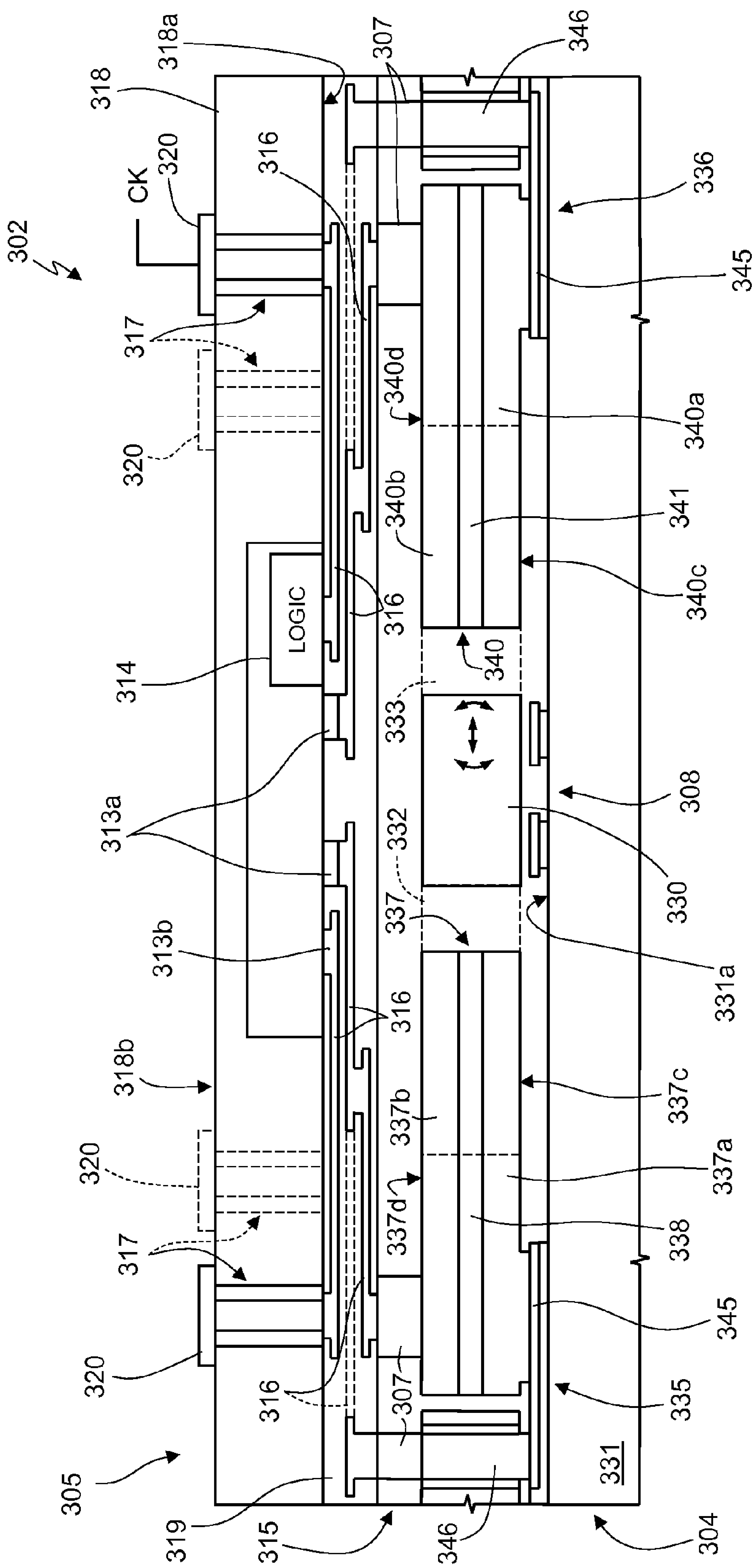

302
305
304
318
318a
318b
319
320
CK
317
316
314
LOGIC
313a
313b
315
307
346
345
336
335
340
340a
340b
340c
340d
341
333
332
330
308
331a
331
337
337a
337b
337c
337d
338

Fig.11

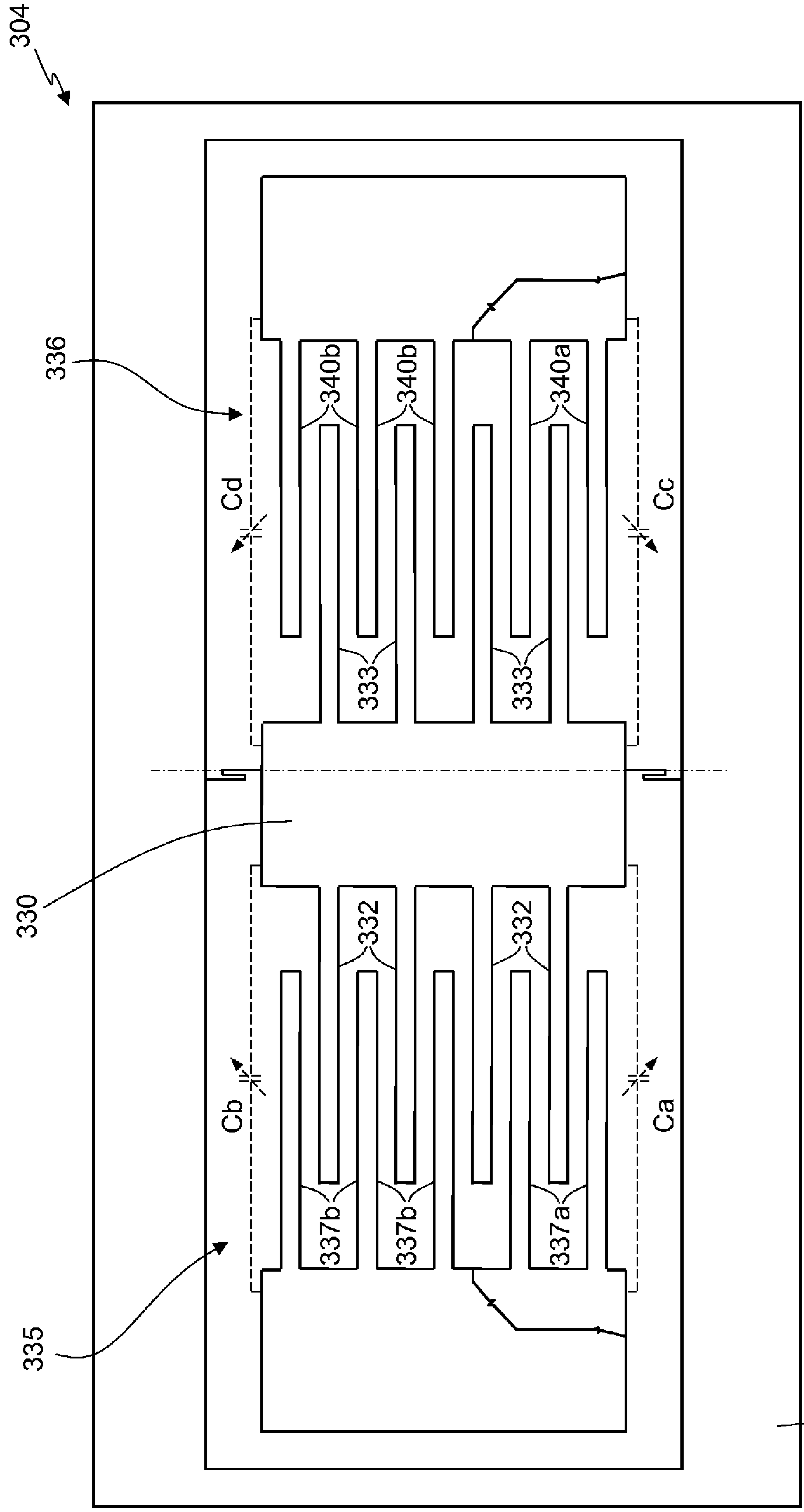

304
336
340b
340b
340a
Cd
Cc
333
333
330
332
332
Cb
Ca
337b
337b
337a
335
331

Fig.12

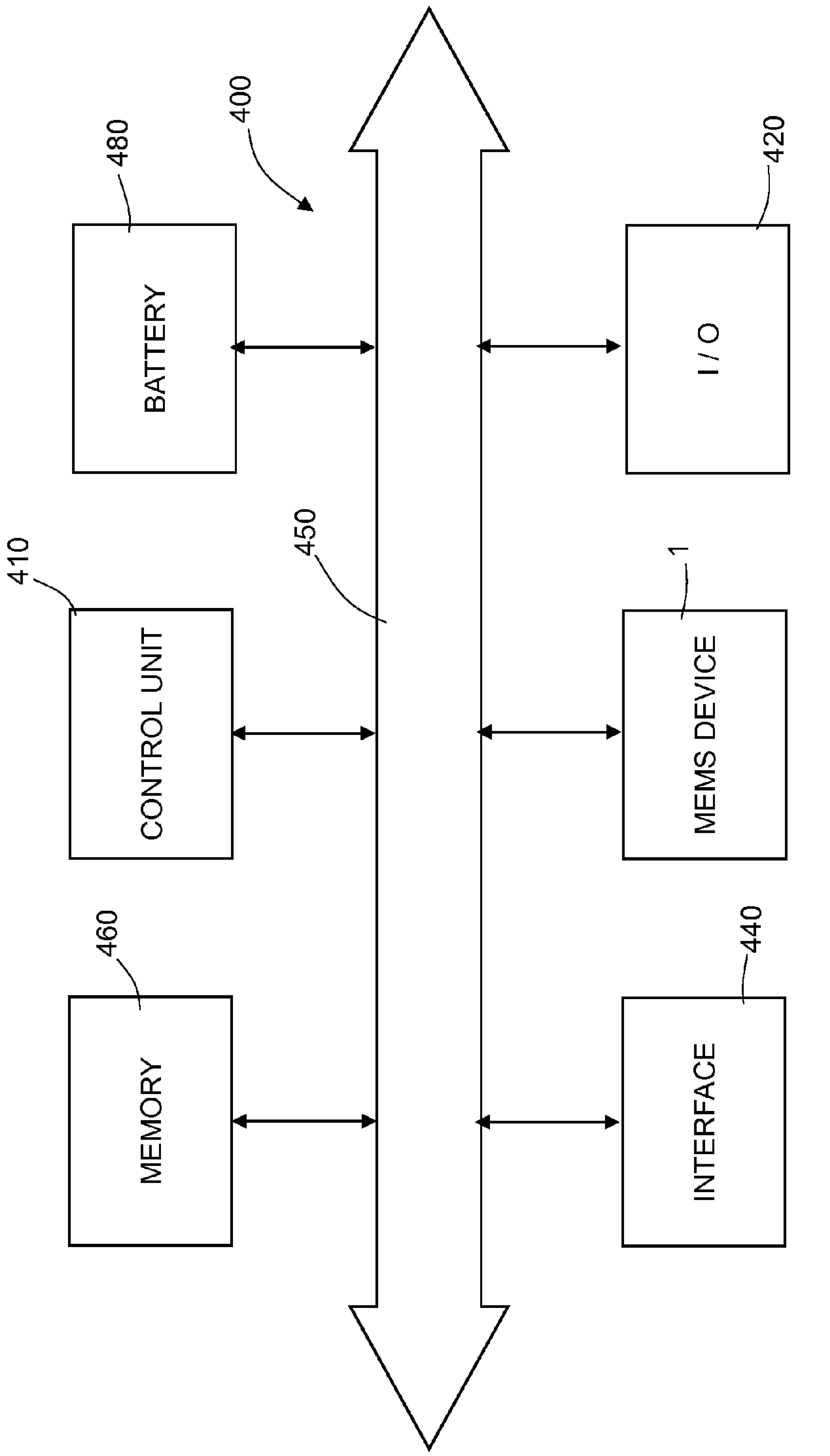

400
480
BATTERY
420
I / O
410
CONTROL UNIT
450
1
MEMS DEVICE
460
MEMORY
440
INTERFACE

Fig.13

MICROELECTROMECHANICAL DEVICE WITH SIGNAL ROUTING THROUGH A PROTECTIVE CAP

BACKGROUND

Technical Field

The present disclosure relates to a microelectromechanical device with signal routing through a protective cap and to a method of controlling the microelectromechanical device.

Description of the Related Art

As is known, the use of microelectromechanical systems (MEMS) has encountered an ever-increasing spread in various sectors of technology and has yielded encouraging results especially in the production of inertial sensors, microintegrated gyroscopes, and electromechanical oscillators for a wide range of applications.

Under the thrust of the increasing request for high performance and flexibility of use, the technology has rapidly developed and has led to the production of miniaturized microelectromechanical sensors capable of detecting different independent quantities. For example, numerous solutions have been proposed regarding multiaxial movement sensors (accelerometers and gyroscopes) using microstructures integrated in a single die.

The trend towards miniaturization and to integration has encountered, however, a limit in the need to enable communication of the sensors integrated in the die with the external environment, in particular with the control devices that are typically obtained in separate dice. An important part of the die integrating the microstructures, in fact, is dedicated exclusively to accommodating contact pads for connection with the outside world. Paradoxically, whilst sophisticated solutions from the mechanical and electrical standpoint enable design of extremely compact microstructures, the area used by the pads and by the corresponding connection lines cannot be reduced beyond a certain limit.

Integrated sensors capable of detecting several independent quantities hence use a considerable expenditure in terms of area.

In addition to the technical difficulties to be tackled for design of the connections, the yield per unit area is low, and the cost of the device is high.

BRIEF SUMMARY

The present disclosure is directed to providing a microelectromechanical device and a method of controlling the microelectromechanical device.

One embodiment of the present disclosure is directed to a microelectromechanical device that includes a body including a microelectromechanical structure, a cap bonded to the body and electrically coupled to the microelectromechanical structure through conductive bonding regions. The cap includes a selection module having first selection terminals coupled to the microelectromechanical structure, second selection terminals, and a control terminal configured to couple the second selection terminals to respective ones of the first selection terminals in accordance with one of a plurality of coupling configurations corresponding to a respective one of a plurality of operating conditions.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

For a better understanding of the disclosure, some embodiments thereof will now be described, purely by way of non-limiting example and with reference to the attached drawings, wherein:

FIG. **1** is a simplified top plan view of a microelectromechanical device according to an embodiment of the present disclosure;

FIG. **2** is a simplified block diagram of the microelectromechanical device of FIG. **1**;

FIG. **3** is a cross section through a portion of the microelectromechanical device FIG. **1**;

FIG. **4** is a simplified electrical diagram of a detail of the microelectromechanical device of FIG. **1**;

FIG. **5** is a simplified electrical diagram of a variant of the detail of FIG. **4**;

FIG. **6** shows graphs regarding quantities used in the microelectromechanical device according to the variant of FIG. **5**;

FIG. **7** shows tables regarding logic functions used in the microelectromechanical device according to the variant of FIG. **5**;

FIG. **8** is a simplified block diagram of a microelectromechanical device according to a different embodiment of the present disclosure;

FIG. **9** is a top plan view of a microelectromechanical device according to a further embodiment of the present disclosure;

FIG. **10** is a cross section through a portion of a microelectromechanical device according to a further embodiment of the present disclosure;

FIG. **11** is a cross section through a portion of a microelectromechanical device according to a further embodiment of the present disclosure;

FIG. **12** is a simplified top plan view with parts removed of the microelectromechanical device of FIG. **11**; and

FIG. **13** is a simplified block diagram of an electronic system incorporating a microelectromechanical device according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

With reference to FIGS. **1** and **2**, a multiaxial microelectromechanical sensor is illustrated schematically and is designated as a whole by **1**. The microelectromechanical sensor **1** comprises a structural component **2** and a control circuit or ASIC (Application-Specific Integrated Circuit) **3**.

The structural component **2** in turn comprises a microstructure chip **4** and a protective cap **5**, bonded to one another through conductive bonding regions **7**, see FIG. **3**.

According to an embodiment, the microstructure chip **4** accommodates a first microelectromechanical structure **8** and a second microelectromechanical structure **10**, which form structural parts, respectively, of a multiaxial accelerometer and of a multiaxial gyroscope of a capacitive type. In what follows, these microelectromechanical structures will be referred to, for simplicity, as "microstructure **8**" and "microstructure **10**".

The first microstructure **8** and the second microstructure **10** have respective sets of terminals **8*a***, **10*a*** coupled to the protective cap **5** through respective conductive bonding regions **7** (FIG. **3**).

The protective cap **5** is bonded to the microstructure chip **4** not only through the conductive bonding regions **7**, but also through a bonding ring (not shown) and is arranged to protect the microstructures **8**, **10**. The bonding ring and the conductive bonding regions **7** are preferably made from a single conductive bonding layer and are made of the same conductive material. However, the conductive bonding regions **7** are electrically insulated from the bonding ring to enable proper routing of the signals.

The protective cap **5** comprises a selection module **13**, a driving module **14**, a routing structure **15**, and through vias **17**, for example of the TSV (through silicon via) type.

The selection module **13** and the driving module **14** are made in a portion of the protective cap **5**, which, for convenience, will be hereinafter referred to as "substrate" **18**. It is understood, however, that this portion of the protective cap **5** may comprise, in addition to a semiconductor substrate proper, further polycrystalline and monocrystalline semiconductor layers and dielectric layers or portions of layers, according to what may be desired to make the selection module **13**, as well as the driving module **14**.

The selection module **13** and the driving module **14** are accommodated in the proximity of a face **18***a* of the substrate **18** that is adjacent to the routing structure **15**.

The routing structure **15** comprises a plurality of connection lines **16** arranged on several levels and embedded in a layer of dielectric material **19**. The routing structure **15** hence enables provision of a plurality of fixed and non-coplanar connections between the microstructures **8**, **10** and the selection module **13**, between the selection module **13** and the driving module **14**, and between the selection module **13** and the driving module **14** and contact pads **20** arranged on a face **18***b* of the substrate **18** opposite to the face **18***a* and coupled to respective signal terminals **3***a* of the control device **3** (FIGS. **1** and **2**).

The selection module **13** has a plurality of first selection terminals **13***a*, second selection terminals **13***b*, and control terminals **13***c*, as shown schematically in FIG. **2** and FIG. **4**. The first selection terminals **13***a* of the selection module **13** are coupled to the terminals **8***a*, **10***a* of the first microstructure **8** and of the second microstructure **10** through the routing structure **15** and the bonding regions **7**, as explained hereinafter. The second selection terminals **13***b* are less numerous than the first selection terminals **13***a* and are coupled to respective contact pads **20**. Connection of the second selection terminals **13***b* to the pads **20** is obtained through the routing structure **15** and respective through vias **17**, which traverse the substrate **18** from the face **18***a* adjacent to the routing structure **15** to the opposite face **18***b*.

In the embodiment illustrated herein, such as FIGS. **4** and **5**, the control terminals **13***c* are coupled to respective outputs of the driving module **14**. Alternatively, in the absence of the driving module **14**, the control terminals **13***c* may be directly coupled to respective clock terminals **3***b* of the control device **3**.

The selection module **13** comprises a plurality of switches **21** controlled by the control device **3** (here through the driving module **14**) so as to couple the second selection terminals **13***b* to the first selection terminals **13***a* according to selectively one of a plurality of coupling configurations corresponding to respective operating conditions.

The switches **21** have first conduction terminals coupled to respective first selection terminals **13***a* and second conduction terminals coupled to respective second selection terminals **13***b*, as shown by way of example in FIG. **4**. Moreover, control terminals of the switches **21** define respective control terminals **13***c* of the selection module **13**. In greater detail, in one embodiment the first conduction terminals of the switches **21** are coupled to respective distinct first selection terminals **13***a*. Groups **21***a* of switches **21** have, instead, the respective second conduction terminals coupled to one and the same second selection terminal **13***b*.

The switches **21** are controlled in such a way that in each group **21***a* just one switch **21** at a time is closed, whilst all the others are open.

In one embodiment (FIG. **5**), the microstructures **8**, **10** provide acceleration signals AX, AY, AZ and angular-velocity signals ΩX, ΩY, ΩZ to respective first terminals **13***a*', **13***a*". For simplicity, the case of unipolar signals is illustrated herein, but what has been explained applies indifferently also to the case of differential signals, except for the fact that a different number of first terminals **13***a*, second terminals **13***b*, and switches **21** is required. The first terminals **13***a*', which receive the acceleration signals AX, AY, AZ, are selectively connectable to one and the same second terminal **13***b*′ through a first group **21***a*' of switches **21**', whereas the first terminals **13***a*", which receive the angular-velocity signals ΩX, ΩY, ΩZ, are selectively connectable to one and the same second terminal **13***b*″ through a second group **21***a*″ of switches **21**". The switches **21**' of the first group **21***a*′ and the switches **21**" of the second group **21**'*a*′ are closed selectively one at a time in rotation during operation of the microelectromechanical sensor **1**.

With reference once again to FIGS. **1**-**3**, the driving module **14** has inputs coupled to respective clock terminals **3***b* of the control device **3** through the routing structure **15**, the through vias **17**, and the pads **20** on the face **18***b* of the substrate **18**. The driving module **14** receives clock signals CK**1**, . . . , CKM from the control device **3** and generates control signals SC**1**, . . . , SCN for the switches **21**. The control signals SC**1**, . . . , SCN, which may be shared by switches **21** of distinct groups **21***a*, are provided to the control terminals **13***c* of the selection module **13** for determining a state (open or closed) of each switch **20**. In this way, the driving module **14** determines the configuration of the selection module **13** and the operating condition of the microelectromechanical sensor **1**.

In the example of FIG. **5**, two clock signals CK**1**, CK**2** are provided in parallel to respective inputs of the driving module **14**. Alternatively, the clock signals may be provided in series through a single terminal or a small number of terminals. The clock signals CK**1**, CK**2** assume in sequence the values illustrated in FIG. **6** during a step of reading the signals coming from the microstructures **8**, **10** and simultaneously a zero value when the microelectromechanical sensor **1** is not in the reading step, such as for example during steps of power-on or entry into or exit from energy-saving (power-down) configuration. The driving module **14** comprises logic blocks **24** that implement respective logic functions F**1**, F**2**, F**3** to generate three control signals SC**1**, SC**2**, SC**3** as a function of the clock signals CK**1**, CK**2**. The control signals SC**1**, SC**2**, SC**3** are provided each to the control terminals of a respective switch **21**' of the first group **21***a*′ and of a respective switch **21**" of the second group **21***a*″.

The logic functions F**1**, F**2**, F**3** are defined by the tables shown in FIG. **7** in such a way that in each group **21***a*', **21***a*″ all the switches **21**', **21**" will be closed selectively one at a time in rotation in the step of reading the microelectromechanical sensor **1**.

According to a variant, illustrated schematically in FIG. **8**, the microelectromechanical sensor **1** comprises a selection module **13*** provided with memory and autonomous processing capability and generates the sequences of control signals SC**1**, . . . , SCN necessary for proper operation starting from a single clock signal CK provided by the control device **3**.

In this case, a single clock terminal **3***b* is sufficient on the control device **3**, and a single pad **20** is sufficient on the protective cap, in addition to the pads **20** necessary for coupling to the signal terminals **3***a*.

According to the embodiment illustrated in FIG. **9**, a structural component **102** of a microelectromechanical sensor **100** comprises a microstructure chip **104**, accommodating a first microstructure **108** and a second microstructure **110**, and a protective cap **105**. The protective cap **105** integrates a selection module **113**, a driving module **114**, and a routing structure (not shown) substantially as already described. On the protective cap **105** contact pads **120** are made for microstructures accommodated in the microstructure chip **104**.

The microstructure chip **104** projects on at least one side with respect to the protective cap and, on the free portion, accommodates further contact pads **120'**.

FIG. **10** shows a structural component **202** of a microelectromechanical sensor according to a further embodiment of the disclosure. The microelectromechanical sensor is not illustrated entirely and comprises, in addition to the structural component **202**, a control device or ASIC substantially as already described.

The structural component **202** comprises a microstructure chip **204** and a protective cap **205**, bonded to each other by conductive bonding regions **207**.

The microstructure chip **204** accommodates a first microstructure **208** and a second microstructure **210** that form structural parts, respectively, of a biaxial accelerometer (with in-plane detection) and of a uni-axial accelerometer (with out-of-plane detection).

In detail, the first microstructure **208** comprises a first detection mass **230** made of semiconductor material, which is constrained to a substrate **231** of the microstructure chip **204** by elastic connection elements (here not shown). The first detection mass **230** is movable with respect to the substrate **231** according to two independent translational degrees of freedom and can oscillate about a position of equilibrium. The first detection mass **230** is provided with plane movable electrodes **232** (represented with a dashed line), capacitively coupled to respective fixed electrodes **235**, which are also plane, anchored to the substrate **231**. Further movable and fixed electrodes, not shown, are arranged in a plane perpendicular to the moveable electrodes **232** and to the fixed electrodes **235**.

The second microstructure **210** comprises a second detection mass **240**, which is also made of semiconductor material and is constrained to the substrate **231** through further elastic connection elements (not shown) so as to oscillate about an axis A parallel to a face **231***a* of the substrate **231**. The second detection mass **240** defines a movable electrode and is capacitively coupled to a fixed electrode **243** formed on the substrate **231**.

The movable electrodes **232** and the fixed electrodes **235** of the first microstructure **208** are electrically coupled to the protective cap **205** through respective bonding regions **207** (the connections of the movable electrodes **232** exploit also the elastic connection elements and are not visible in FIG. **10**).

The second detection mass **240** is electrically coupled to the protective cap **205** through the elastic connection elements and respective bonding regions (the connections of the second detection mass **240** are not visible in FIG. **10**).

The fixed electrode **243** of the second microstructure **210** is electrically coupled to the protective cap **205** through connection lines **245** that develop on the substrate **231**, conductive plugs **246**, and respective bonding regions **207**.

The protective cap **205** is bonded to the microstructure chip **204** through the bonding regions **207** and a bonding ring (not shown) and is arranged as protection for the microstructures **208**, **210**. The bonding ring and the conductive bonding regions **207** are preferably made of one and the same conductive bonding layer and are made of one and the same conductive material. However, the conductive bonding regions **207** are electrically insulated from the bonding ring to enable proper signal routing.

The protective cap **205** comprises a selection module **213** accommodated in a substrate **218**, a routing structure **215**, and through vias **217**. In this case, the protective cap **205** is without an independent driving module, and possible logic functions are incorporated in the selection module **213** (schematically designated by the number **214**).

The routing structure **215** comprises metal connection lines **216**, embedded in a dielectric layer **219** and arranged on a number of distinct levels. The metal connection lines **216** are made, for example, of copper and are obtained using a “damascene” technique.

The selection module **213** is accommodated in the proximity of a face **218***a* of the substrate **218** adjacent to the routing structure **215** and has a plurality of first selection terminals **213***a* and second selection terminals **213***b*. The first selection terminals **213***a* are coupled to the first microstructure **208** and to the second microstructure **210** through the routing structure **215** and the bonding regions **207**. The second selection terminals **213***b* are less numerous than the first selection terminals **213***a* and are coupled to respective contact pads **220** set on a face **218***b* of the substrate **218** opposite to the face **218***a*. The connection of the second selection terminals **213***b* to the pads **220** is obtained through the routing structure **215** and respective through vias **217**, which traverse the substrate **218** from the face **218***a* to the opposite face **218***b*.

The selection module **213** is made substantially as already described and comprises a plurality of switches (here not shown) controlled so as to couple the second selection terminals **213***b* to the first selection terminals **213***a* according, selectively, to one of a plurality of coupling configurations corresponding to respective operating conditions. In this case, the selection module **213** is provided with memory and autonomous processing capability and receives a clock signal CK that is used to configure the connection of the second selection terminals **213***b* to the first selection terminals **213***a*.

FIG. **11** shows a structural component **302** of a microelectromechanical sensor according to a further embodiment of the disclosure. The microelectromechanical sensor is not illustrated entirely and comprises, in addition to the structural component **302**, a control device or ASIC substantially as already described.

The structural component **302** comprises a microstructure chip **304** and a protective cap **305**, bonded to each other by conductive bonding regions **307**.

The microstructure chip **304** accommodates a microstructure **308** that forms structural parts of a biaxial accelerometer.

In greater detail, the microstructure **308** comprises a detection mass **330** made of semiconductor material, mechanically coupled to a substrate **331** of the microstructure chip **304** so as to have two degrees of freedom (a translational degree of freedom and a rotational degree of freedom about a non-centroidal axis in the embodiment described herein).

The detection mass **330** is provided with two groups of movable electrodes **332**, **333** in the form of plane plates that extend in comb-like fashion in planes parallel to one another and perpendicular to a face **331***a* of the substrate **331**. In addition, the two groups of movable electrodes **332**, **333** are substantially symmetrical.

The microstructure **308** further comprises two groups of fixed electrodes **335**, **336**, fixed to the substrate **331** and capacitively coupled to the groups of movable electrodes **332**, **333**, respectively.

The group of fixed electrodes **335** comprises electrode structures **337**, which are also in the form of plane plates that extend in comb-like fashion towards the detection mass **330**. The movable electrodes **332** and the electrode structures **337** extend towards one another and are comb-fingered.

Each electrode structure **337** comprises a respective first fixed electrode **337***a* and a respective second fixed electrode **337***b*, both made of polycrystalline silicon and insulated from one another by a dielectric region **338**. The first fixed electrode **337***a*, the dielectric region **338**, and the second fixed electrode **337***b* form in order a stack in the direction perpendicular to the face **331***a* of the substrate **331**. The first fixed electrode **337***a* occupies a portion of the fixed-electrode structure **337** that extends between the dielectric region **338** and a margin **337***c* facing the substrate **331**. The second fixed electrode **337***b* occupies, instead, a portion of the electrode structure **337** that extends between the dielectric region **338** and a margin **337***d* opposite to the margin **337***c* and facing the protective cap **305**.

The group of fixed electrodes **336** is rigidly fixed to the substrate **331**, in a position opposite to the group of fixed electrodes **335** with respect to the movable mass **330**. The group of fixed electrodes **336** comprises electrode structures **340** which are also in the form of plane plates that extend in comb-like fashion towards the detection mass **330** in planes parallel to one another and perpendicular to the face **331***a* of the substrate **331**. The movable electrodes **333** and the electrode structures **340** extend towards one another and are comb-fingered.

Each electrode structure **340** comprises a respective first fixed electrode **340***a* and a respective second fixed electrode **340***b*, both made of polycrystalline silicon and are insulated from one another by a dielectric region **341**. The first fixed electrode **340***a*, the dielectric region **341**, and the second fixed electrode **340***b* form in order a stack in a direction perpendicular to the face **331***a* of the substrate **331**. The first fixed electrode **340***b* (coplanar to the first fixed electrode **337***a* of a corresponding electrode structure **337**) occupies a portion of the fixed-electrode structure **340** that extends between the dielectric region **341** and a margin **340***c* facing the substrate **331**. The fourth fixed electrode **340***b* (coplanar to the second fixed electrode **337***b* of a corresponding electrode structure **337**) occupies, instead, a portion of the electrode structure **340** that extends between the dielectric region **341** and a margin **340***d* opposite to the margin **340***c* and facing the protective cap **305**.

The first fixed electrodes **337***a*, **340***a* of the electrode structures **337**, **340** are coupled to respective electrical connection lines **345**, which develop on the substrate **331** and are coupled to the protective cap **305** through conductive plugs **346** and respective bonding regions **307**.

The second fixed electrodes **337***b*, **340***b* of the electrode structures **337**, **340** are bonded to the protective cap **305** through respective bonding regions **307**.

As shown in a simplified way in FIG. **12**, the first fixed electrodes **337***a* and the second fixed electrodes **337***b* of the electrode structures **337** are capacitively coupled to respective movable electrodes **332** of the detection mass **3** and define with the latter respective capacitors that have an overall capacitance Ca, Cb. The third fixed electrodes **340***a* and fourth fixed electrodes **340***b* of the fixed-electrode structures **340** are capacitively coupled to respective movable electrodes **333** of the detection mass **3** and define with the latter respective capacitors that have overall capacitance Cc, Cd.

With reference once again to FIG. **11**, the protective cap **305** comprises a selection module **313** accommodated in a substrate **318**, a routing structure **315**, and through vias **317**.

The routing structure **315** comprises metal connection lines **316**, embedded in a dielectric layer **319** and arranged on a number of distinct levels.

The selection module **313** is accommodated in the proximity of a face **318***a* of the substrate **318** adjacent to the routing structure **315** and has a plurality of first selection terminals **313***a* and second selection terminals **313***b*. The first selection terminals **313***a* are coupled to the microstructure **308** through the routing structure **315** and the bonding regions **307**. The second selection terminals **313***b* are less numerous than the first selection terminals **313***a* and are coupled to respective contact pads **320** set on a face **318***b* of the substrate **318** opposite to the face **318***a*. Connection of the second selection terminals **313***b* to the pads **320** is obtained through the routing structure **315** and respective through vias **317**, which traverse the substrate **318** from the face **318***a* to the opposite face **318***b*.

The selection module **313** is made substantially as already described and comprises a plurality of switches (here not shown) controlled so as to couple the second selection terminals **313***b* to the first selection terminals **313***a* according to selectively one of a plurality of coupling configurations corresponding to respective operating conditions. In this case, the selection module **313** is provided with memory and autonomous processing capability for implementing logic control functions (designated as a whole by the number **314**) and receives a clock signal CK that is used to configure the connection of the second selection terminals **313***b* to the first selection terminals **313***a*.

The use of a selection module and of contact pads on the protective cap advantageously enables space to be freed on the microstructure chip and a greater area to be made available for the microstructures. It should in fact be considered that there is no need to arrange the pads exclusively around the microstructures. The pads may be provided also in regions of the cap that overly both the microstructures and the selection module, as well as the driving module (see in this connection in FIG. **1** the pads **20** with respect to the microstructures **8**, **10**, to the selection module **13**, and to the driving module **14**).

The number of pads necessary for connection towards the outside world, in particular towards the control device, is small, also considering the pads necessary to control the switches. Consequently, the design is simplified, also owing to the greater flexibility in the development of the connection lines, and it is possible to provide pads of large dimensions, favoring subsequent provision of the contacts.

FIG. **13** illustrates a portion of an electronic system **400** according to one embodiment of the present disclosure. The system **400** incorporates the microelectromechanical device **1** and may be used in devices such as, for example, a palm-top computer (personal digital assistant, PDA), a laptop or portable computer, possibly with wireless capability, a cellphone, a messaging device, a digital music player, a digital camera, or other devices designed to process, store, transmit, or receive information. For example, the microelectromechanical device **1** may be used in a digital camera to detect movements and carry out an image stabilization. In a further embodiment, the microelectromechanical device **1** is included in a motion-activated user interface for computers or consoles for videogames. In a further embodiment, the microelectromechanical device **1** is incorporated in a satellite-navigation device and is used for temporarily tracking the position in the case of loss of the satellite positioning signal.

The electronic system **400** may comprise a controller **410**, an input/output (I/O) device **420** (for example, a keyboard or a display), the microelectromechanical device **1**, a wireless interface **440**, and a memory **460**, of a volatile or nonvolatile type, which are coupled to each other through a bus **450**. In one embodiment, a battery **480** may be used to provide the system **400**. It should be noted that the scope of the present disclosure is not limited to embodiments having necessarily one or all of the devices listed.

The controller **410** may comprise, for example, one or more microprocessors, microcontrollers, and the like.

The I/O device **420** may be used to generate a message. The system **400** may use the wireless interface **440** to transmit and receive messages to and from a wireless communication network with a radiofrequency (RF) signal. Examples of wireless interface may comprise an antenna, a wireless transceiver, such as a dipole antenna, even through the scope of the present disclosure is not limited from this standpoint. Moreover, the I/O device **420** may provide a voltage representing what is stored either in the form of digital output (if digital information has been stored) or in the form of analog output (if analog information has been stored).

Modifications and variations may be made to the microelectromechanical device and to the method described, without thereby departing from the scope of the present disclosure.

In particular, the microelectromechanical device may incorporate one or more microelectromechanical sensors of any type, but also micromotors and microactuators.

Grouping and driving of the switches of the selection module may obviously vary and is basically determined by the mode of operation of the sensors, micromotors, or microactuators incorporated in the device.

In addition, the switches of the selection module may be arranged also on different selection levels, for example according to a tree structure.

The various embodiments described above can be combined to provide further embodiments. These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

The invention claimed is:

1. A method, comprising:

controlling a microelectromechanical device, the device having a composite structure that includes a body having a microelectromechanical structure including a plurality of output terminals, a cap bonded to the body and electrically coupled to the microelectromechanical structure through conductive bonding regions, and in the cap, a selection module having first selection terminals coupled to respective ones of the plurality of output terminals of the microelectromechanical structure, a second selection terminal, and a control terminal, the controlling including:

outputting, by the selection module, a signal provided at a respective one of the output terminals by selectively coupling one of the first selection terminals to the second selection terminal in accordance with one of a plurality of coupling configurations corresponding to a respective one of a plurality of operating conditions.

2. The method of claim **1** wherein the body includes a second microelectromechanical structure including a plurality of second output terminals, and the selection module includes third selection terminals coupled to respective ones of the plurality of second output terminals, and a fourth selection terminal, the controlling further including:

outputting, by the selection module, a signal provided at a respective one of the second output terminals by selectively coupling one of the third selection terminals to the fourth selection terminal.

3. The method of claim **2** wherein the selection module includes a first plurality of switches, each of the first plurality of switches being coupled between a respective first selection terminal and the second selection terminal, and a second plurality of switches, each of the second plurality of switches being coupled between a respective third selection terminal and the fourth selection terminal.

4. The method of claim **1** wherein the selection module includes a first plurality of switches, each of the first plurality of switches being coupled between a respective first selection terminal and the second selection terminal.

5. A device, comprising:

a first substrate including a first sensor having a plurality of first output terminals;

a second substrate having a first surface and a second surface, the first surface being mechanically and electrically coupled to the first substrate, the second substrate being a cap that includes:

a selection module electrically coupled to the first sensor, the selection module including first selection terminals coupled to respective ones of the plurality of first output terminals, and a second selection terminal operatively coupled to a selected one of the first selection terminals, the selection module being configured to output at the second selection terminal a signal provided at a respective one of the first output terminals.

6. The device of claim **5** wherein the first substrate includes a second sensor.

7. The device of claim **6** wherein the selection module is electrically coupled to the second sensor.

8. The device of claim **7**, further comprising:

a redistribution layer formed on the first surface of the second substrate;

electrical connection members formed between the redistribution layer and the first substrate, the electrical connection members being configured to electrically couple the selection module to the first and second sensors.

9. The device of claim **7** wherein the second substrate includes a plurality of contact pads formed on the second surface of the second substrate and a plurality of through vias configured to electrically couple the selection module to the contact pads.

10. The device of claim **6** wherein the second sensor includes a plurality of second output terminals, and the selection module includes second selection terminals coupled to respective ones of the plurality of second output terminals, and a third selection terminal operatively coupled to a second one of the second selection terminals.

11. The device of claim **5** wherein the second substrate includes a driving module electrically coupled to the selection module.

12. The device of claim **11** wherein the first substrate includes a second sensor and the selection module is electrically coupled to the second sensor.

13. The device of claim **12** wherein the second sensor includes a plurality of second output terminals, and the selection module includes:

third selection terminals coupled to respective ones of the plurality of second output terminals; and

a fourth selection terminal operatively coupled to a selected one of the third selection terminals, the selection module being configured to output at the fourth selection terminal a signal provided at a respective one of the second output terminals.

14. The device of claim **13** wherein the selection module includes a first plurality of switches coupled to the first selection terminals and a second plurality of switches coupled to the third selection terminals.

15. The device of claim **14** wherein the selection module includes a first input coupled to the first plurality of switches and a second input coupled to the second plurality of switches.

16. A method, comprising:

forming a first sensor in a first substrate, the first sensor having a plurality of first output terminals;

mechanically and electrically coupling a first surface of a second substrate to the first substrate;

forming a selection module in the second substrate, the selection module including first selection terminals and a second selection terminal configured to be operatively coupled to a selected one of the first selection terminals;

electrically coupling the first selection terminals directly to respective ones of the first output terminals; and

forming a cap with the second substrate.

17. The method of claim **16**, further comprising forming a second sensor in the first substrate.

18. The method of claim **17**, further comprising coupling the selection module to the second sensor.

19. The method of claim **18**, further comprising:

forming a redistribution layer on the first surface of the second substrate;

forming electrical connection members between the redistribution layer and the first substrate, the electrical connection members coupling the selection module to the first and second sensors.

20. The method of claim **18**, further comprising forming a plurality of contact pads on a second surface of the second substrate and coupling a plurality of through vias between the selection module and the contact pads.

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